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THE EXPANSION AND CHANGE OF STRENGTH IN CAST IRON DUE TO REPEATED HEATINGS

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THE EXPANSION AND CHANGE OF STRENGTH IN CAST IRON DUE TO REPEATED HEATINGS

by

JAMES KNIGHT COOK

A Thesis Submitted for the Degree of
BACHELOR OF SCIENCE
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Contents.

Introduction Page 1

Apparatus and Specimens Page 2-3-4

Method Used in Heating First Series of Bars Page 5-6

Method Used in Heating Second Series of Bars Page 7

Conclusions Page 8-9

Suggestions for Future Investigations Page 10-11

Bibliography Page 12

Tables and Curves

Introduction.

In the proceedings of the American Institute of Mining Engineers for February 1904, Mr. Outerbridge of Philadelphia, Pennsylvania, has an article which he has called "The Mobility of Molecules of Cast Iron". In this article he gives a brief account of some experiments with cast iron test bars, which he heated in a case hardening furnace several times, allowing the bars to cool in the furnace after each heat. These bars after cooling were larger than the original ones. He reheated them about fifty times and they had not yet left off expanding. Mr. Outerbridge mentions , in his article, several instances where castings were made too small but were successfully brought to size by two or three heatings in a case hardening furnace.

The amount of permanent expansion of cast iron was found by Mr. Outerbridge, to depend very much upon the chemical condition or grade of cast iron, also upon the degree of temperature to which the bars are heated.

In this thesis, the chemical condition of the iron and the maximum temperature were kept very nearly constant so that the effect of each heating upon this permanent expansion could be determined.

Apparatus and Specimens.

The test specimens were cast iron bars cast on end from the same heat. They were gray foundry iron of high grade, cast from 60 per cent scrap and 40 per cent pig iron. A chemical analysis shows the following:

The bars were cast a little over 19 inches long and 1-1/4 inches in diameter. They were turned in an engine lathe to 19 inches long and 1-1/8 inches in diameter.

In order to have a convenient method for measuring the length of the bars, a twenty-inch micrometer was designed as shown in plate I. Two sliding heads were made to fit the bar (A). These may be adjusted for any desired length of bar, and clamped in position by means of the two thumb screws beneath the head. Two movable rests were made for holding the micrometer in the position shown.

The bars were heated in the Brown and Sharp case hardening furnace in the University foundry. This furnace has a single oven as shown in plate II.

The fire is started on the grate (G) and the flames are carried over the bridge wall, through the oven (C) and into the suction flue (B). The furnace is built of fire brick with iron doors, and is designed for the burning of coal or coke. The heating of the oven is uneven, being hotter at the back of the oven and farthest from the brick wall.

A pyrometer consisting of a thermo-couple and millivoltmeter was used for determining the temperature. The thermo-couple used in the first series of heats was insufficient to withstand the temperature. During the second

Bristol millivoltmeter was used. The calibration curves for these pyrometers are shown on the following plates. The nickle-nickle chromium couple was calibrated with a Keiser & Schmidt standard pyrometer.

Method Used in Heating the First Series of Bars.

In the first series of heats, the bars were cut to a length of 19 inches and were placed in the oven in three layers. The bottom layer of nine bars was placed with the bars running lengthwise with the oven and parallel to the bridge-wall. The bars of the middle layer were placed across these, while those of the top layer were placed parallel to those of the bottom layer. The nickle-nickle chromium couple was inserted through a hole in the top of the top of the oven, with copper wires leading to the Weston multivoltmeter on a ledge near the furnace. The fire was started with the suction turned on and after the bars were placed in the oven, the temperature was allowed to reach 1500 degrees by the pyrometer, when the suction was shut off, the furnace closed and the bars allowed to cool for twenty-four hours in the furnace. Nine heats were made in a similar manner, taking out three bars after each heat, until the three bars taken out last had been subjected to nine heats.

Three bars were carefully measured with the micrometer to find the amount of expansion. They were then broken in Olsen's cross bending machine and the flexural strength obtained from the formula:

$$S\ f = \frac{M\ C}{I}$$

Where M = the bending moment

C = the radius of the bar

I = the moment of inertia

Method Used in Heating the Second Series of Bars.

A second series of nine heats were made with nine bars, one bar being left out each time for the strength test. To eliminate the error due to the difference in chemical condition of the different bars found in the first series of heats, all of the bars were measured after each heat. All of the bars were placed in a wrought iron pipe. This bunched the bars together so that a more even distribution of the heat was secured and also kept the bars from becoming warped.

The fire was started in the furnace two or three hours before the bars were put into the oven and after the temperature had reached 1800 degrees F. by the pyrometer, the heat was held for about 45 minutes to allow the heat to become evenly distributed over the bars. The pyrometer, instead of being inserted in the top of the oven, was pushed through a hole in the door and into the pipe with the bars.

Conclusions.

Due to an uneven distribution of heat in the oven, some of the sets of bars of the first series were not heated up to the temperature indicated by the pyrometer.

There is a temperature a little below 1400 degrees at which very little, if any, permanent expansion takes place. This fact was made evident by some tests made by Mr. Outerbridge. A series of heats were made by him on some cast iron bars at a temperature a little below 1400 degrees, which resulted in practically no expansion.

In the first series of heats, the bars taken out last were nearest the bridge wall and were not as hot as those taken out first. Another reason for the irregularity of the results in the first series is due to the fact that only the three bars taken out each time were measured for the increase in length, and the bars were not cast in exactly the same way.

In the second series, the bars were bunched together in the wrought iron pipe and care was taken to have the temperature evenly distributed over all of the bars.

The results of the second series of reheats show a constant increase in length of about .004 inch for each heat.

The flexural strength decreases more slowly after the first two heats.

Suggestions for Future Investigations.

A more complete investigation of this subject would involve series of reheats at different temperatures and with different sizes of test bars also, with a variation of the different chemical elements in the iron. The variation of the temperature, however, I think is the more important.

The most important precautions to take in running these heats is to have the bars of the same temperature. If the Brown and Sharp case hardening furnace is used, probably the best way to evenly distribute the heat over all of the bars would be to place the bars in a pipe about an inch or two longer than the bars, heat the oven up to the required temperature about an hour before the bars are placed in the oven, then place the pipe bars and all in the oven. It would be well if the ends of the pipe were closed, leaving room for the expansion of the bars, since a wrought iron pipe would not expand with the cast iron. If some means could be found to keep the ends of the bars from scaling or corroding, more accurate determinations of the increase in length would result. It is difficult to determine just how much scale to scrape off of the ends of the bars after they have been heated.

The tool marks can be seen after the bars have been heated, and these show the original surface which should be left on the bars. I think that very little filing is necessary to remove the outer scale.

The Bristol pyrometer gave no trouble at the high temperatures of the second series of heats after the ends were well fused together.

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Am. Soc. of Mech. Eng's. Mid Nov. 1907

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Mr. Outerbridge
Am. Inst. of Min. Eng's. Feb 1904

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Mr. Outerbridge
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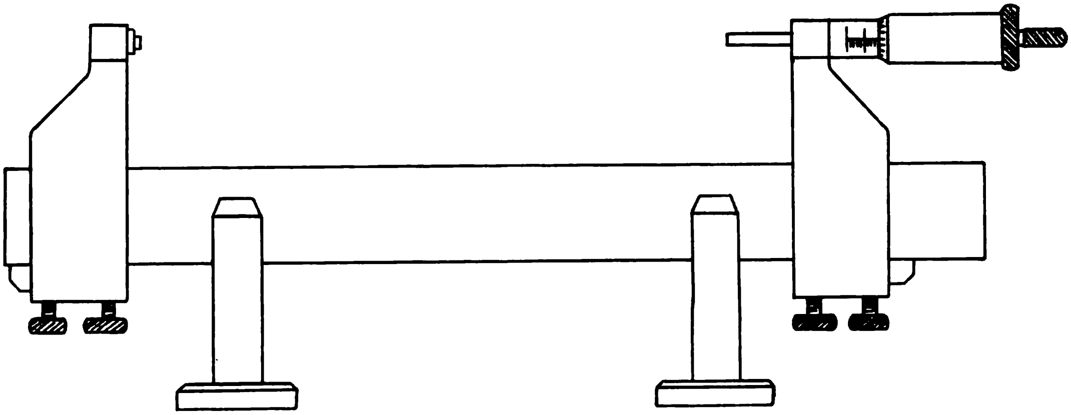
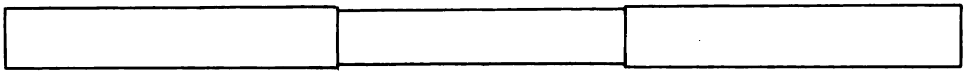
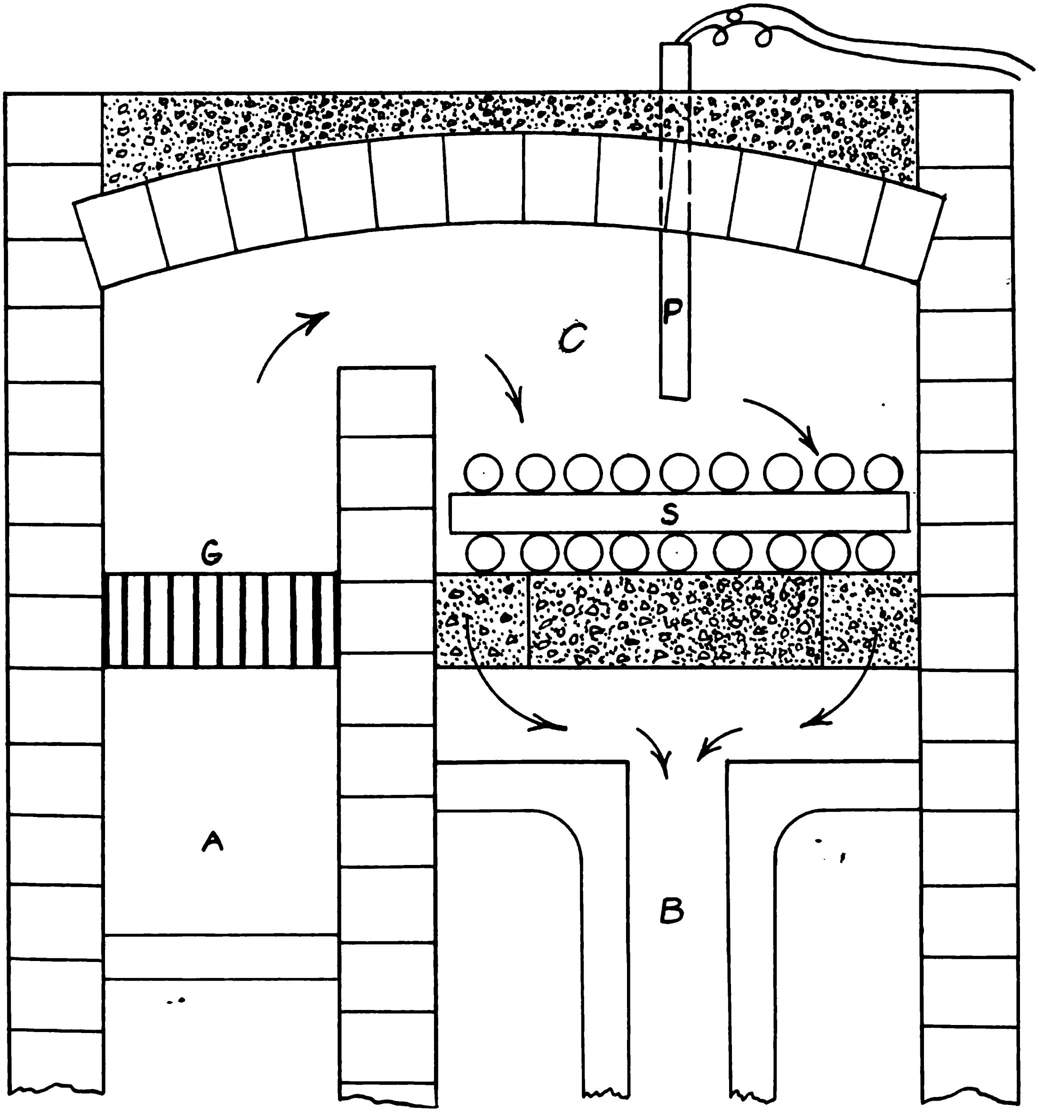


Twenty-inch micrometer, used for measuring the length of the test bars.



Form of test bar 19 inches long by 1¼ inches in diameter, turned to 1-1/8 inches in the middle.

PLATE I.



Arrangement of the Brown and Sharpe case hardening furnace.

PLATE II.

Increase in Length (First Series).

Bar	Times Heated	Original Length	Final Length	Increase	Average	Unit Increase
4		19.002	19.128	.126		
5		19.005	19.128	.123		
6	1	19.011	19.146	.135	.128	.00674
7		19.003	19.169	.166		
8		19.009	19.163	.154		
9	2	19.011	19.171	.160	.160	.00835
10		19.000	19.169	.169		
11		18.992	19.120	.128		
12	3	19.000	19.117	.117	.138	.00725
13		19.013	19.116	.103		
14		19.009	19.118	.109		
15	4	19.000	19.111	.111	.108	.00568
16		18.999	19.138	.139		
17		18.998	19.131	.133		
18	5	19.002	19.222	.120	.131	.0069
19		19.000	19.187	.187		
20		18.998	19.191	.193		
21	6	19.001	19.214	.213	.198	.0141

Bar	Times Heated	Original Length	Final Length	Increase	Average Increase	Unit Increase
22		19.004	19.156	.152		
23		18.996	19.160	.164		
24	7	19.001	19.149	.148	.155	.00816
25		18.999	19.128	.129		
26		18.973	19.089	.112		
27	8	19.003	19.122	.119	.120	.00632
28		19.002	19.116	.114		
29		19.000	19.114	.114		
30	9	19.003	19.119	.116	.115	.00605

Flexural Strength.

Bar	Times Heated	Load	Average	Flexural Stress
1		3000		
2		2890		
3		2990	2960	126000
4		2330		
5		2000		
6	1	2440	2257	95900
7		2340		
8		2200		
9	2	2380	2307	98100
10		2150		
11		2400		
12	3	2340	2297	97500
13		2520		
14		2210		
15	4	2150	2293	97500
16		2450		
17		2260		
18	5	2290	2333	99000

Bar	Times Heated	Load	Average	Flexural Stress
19		2450		
20		2300		
21	6	2100	2283	97200
22		2440		
23		2250		
24	7	2120	2270	96500
25		2350		
26		2360		
27	8	2340	2350	99700
28		2360		
29		2400		
30	9	2390	2383	101200

Bar	Times Heated	Load	Average	Flexural Stress
19		2450		
20		2300		
21	6	2100	2283	97200
22		2440		
23		2250		
24	7	2120	2270	96500
25		2350		
26		2360		
27	8	2340	2350	99700
28		2360		
29		2400		
30	9	2390	2383	101200

Increase in Length (Second Series).

No. of Heat		1	2	3	4	5	6	7	8	9
Bar	Not Heated									
2	19.047	19.161								
3	19.071	19.212	19.346							
4	19.070	19.180	19.310	19.385						
5	18.970	19.102	19.275	19.350	19.400					
6	19.020	19.155	19.297	19.362	19.440	19.525				
7	19.059	19.175	19.313	19.390	19.490	19.605	19.688			
8	19.048	19.175	19.318	19.378	19.450	19.540	19.630	19.697		
9	19.081	19.207	19.347	19.412	19.470	19.567	19.637	19.696	19.768	
10	19.053	19.160	19.282	19.373	19.430	19.525	19.590	19.651	19.727	19.797

Increase in Length (Second Series).

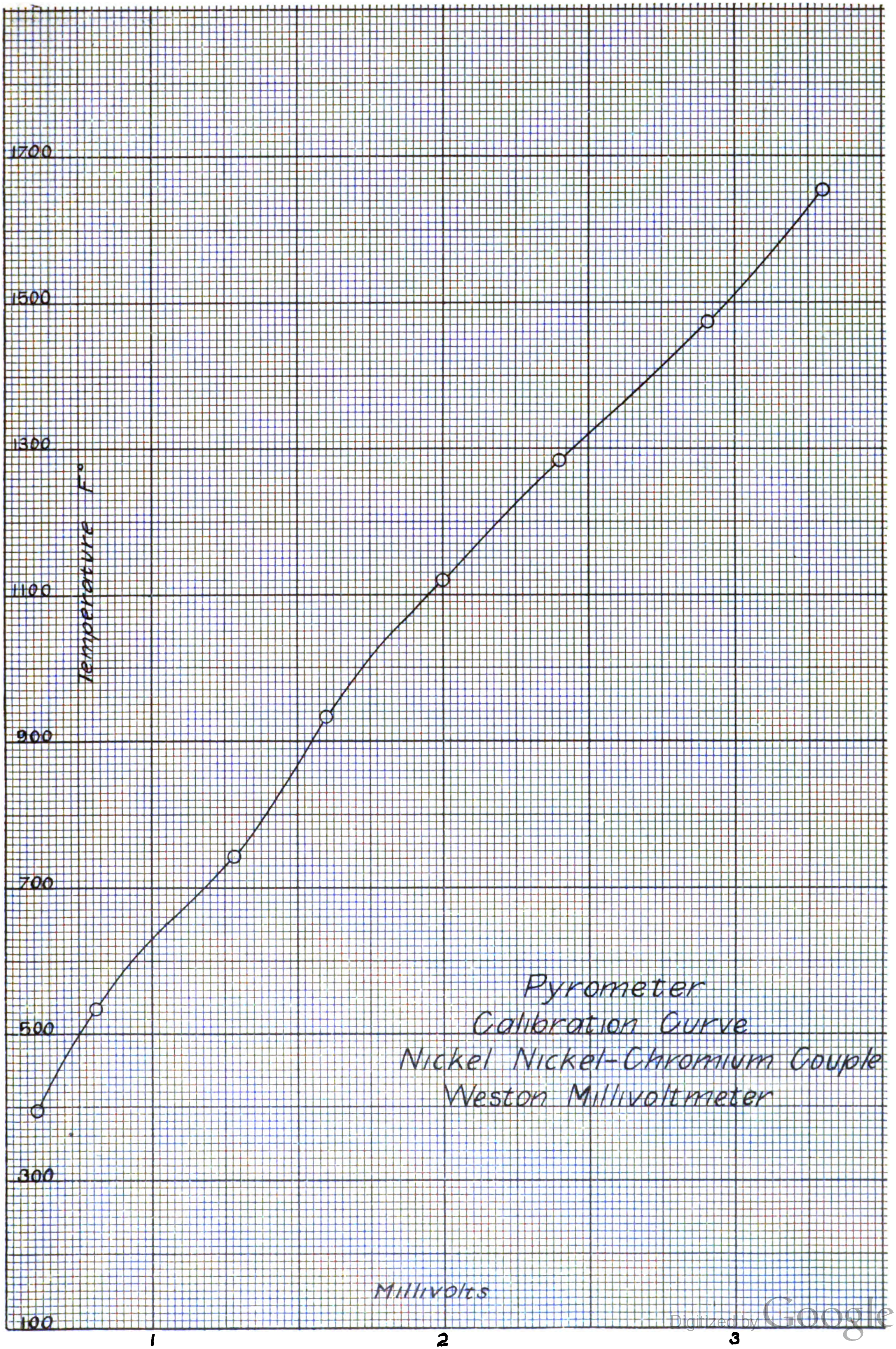
Times Heated	1	2	3	4	5	6	7	8	9
Bar									
2	.114								
3	.141	.275							
4	.110	.240	.315						
5	.132	.305	.380	.430					
6	.135	.277	.342	.420	.505				
7	.116	.254	.331	.431	.546	.629			
8	.127	.270	.330	.403	.492	.582	.649		
9	.126	.266	.331	.389	.480	.556	.615	.687	
10	.107	.233	.320	.377	.472	.537	.598	.674	.744
Average Increase	.122	.265	.336	.408	.499	.576	.621	.680	.744
Unit Increase	.0064	.0139	.0176	.0215	.0262	.0303	.0326	.0358	.0391

Flexural Tests.

Bar No.	1	2	3	4	5	6	7	8	9	10
Deflection										
.02	380	360	330	370	320	300	270	270	260	250
.04	670	580	630	650	580	490	490	500	470	440
.06	970	890	930	930	830	760	710	730	670	640
.08	1230	1100	1190	1200	1040	980	900	930	860	830
.10	1480	1300	1400	1390	1230	1190	1070	1105	1030	980
.12	1680	1450	1570	1530	1370	1330	1180	1220	1150	1090
.14	1850	1550	1660	1650	1470	1440	1260	1330	1240	1180
.16	1990	1640		1700	1560	1540	1360	1380	1300	
.18	2100	1660			1630	1620			1360	
.20					1700	1670				
.22						1730				
.24						1760				

Flexural Strength.

No.	Load	Flexural Stress	No. of Heats
1	2100	128520	Not heated
2	1660	101600	1
3	1660	101600	2
4	1700	104000	3
5	1700	104000	4
6	1540	94300	5
7	1360	83250	6
8	1380	84500	7
9	1360	83250	8
10	1180	72200	9



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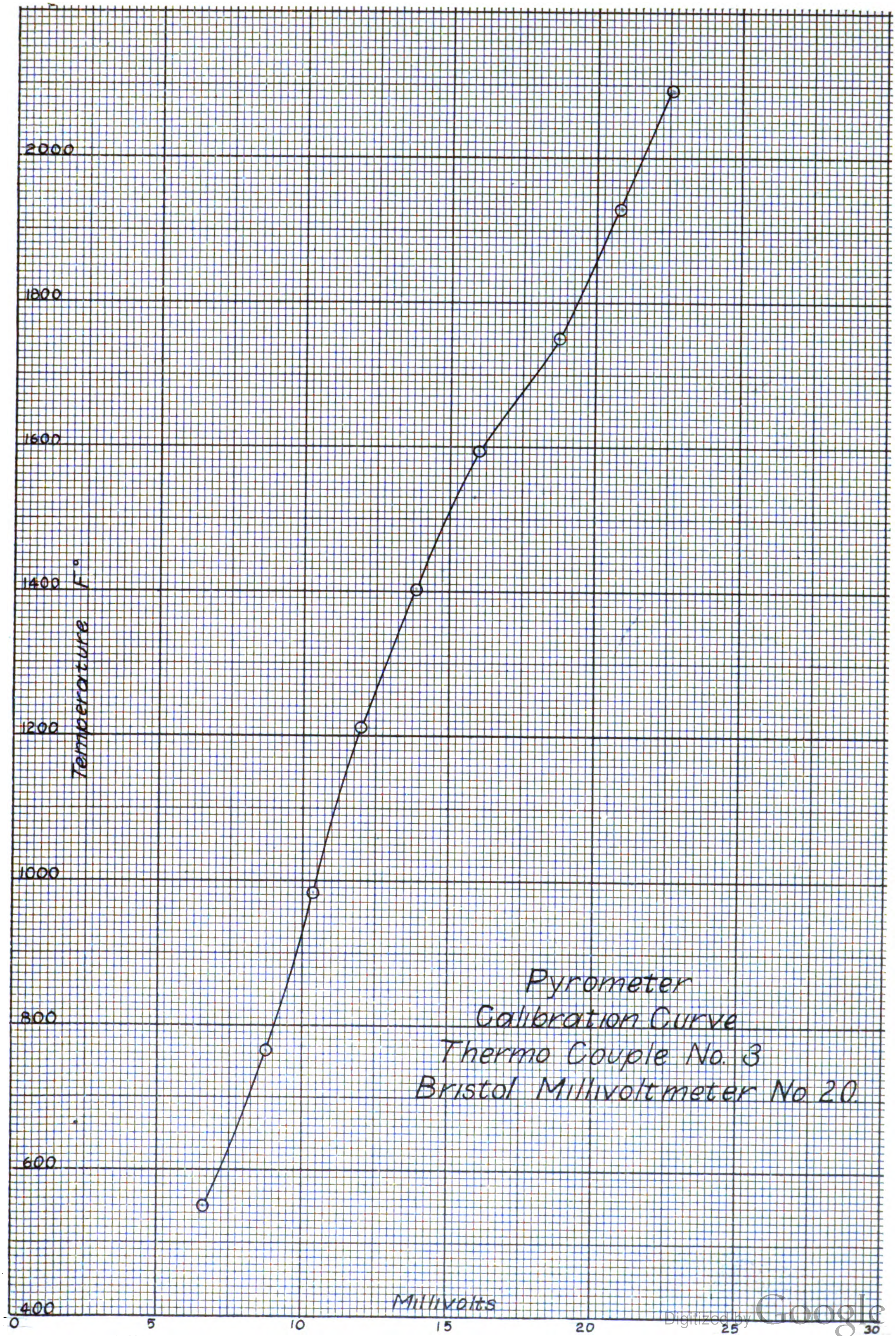

Pyrometer
Calibration Curve
Thermo Couple No. 3
Bristol Millivoltmeter No 20.

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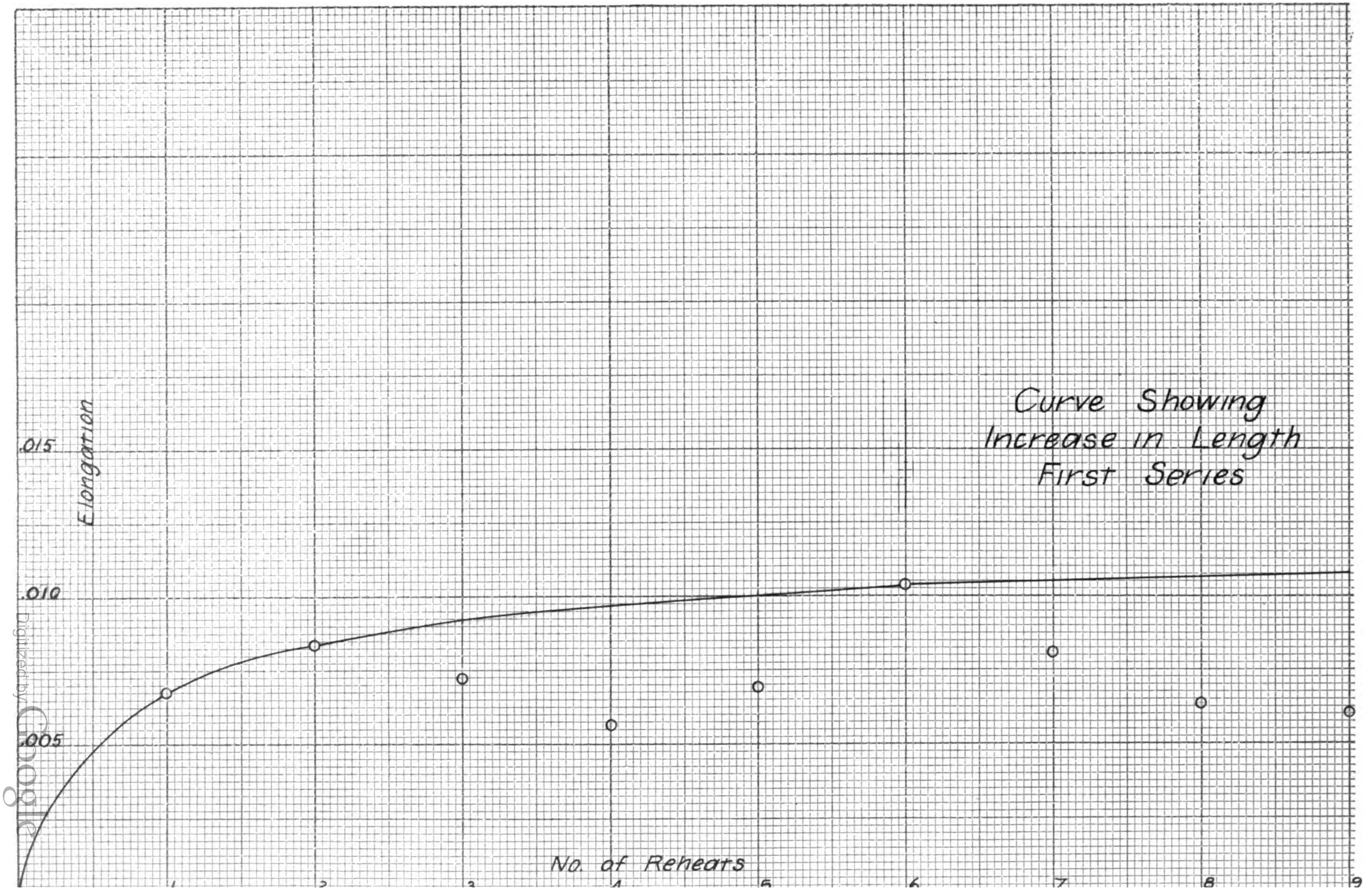
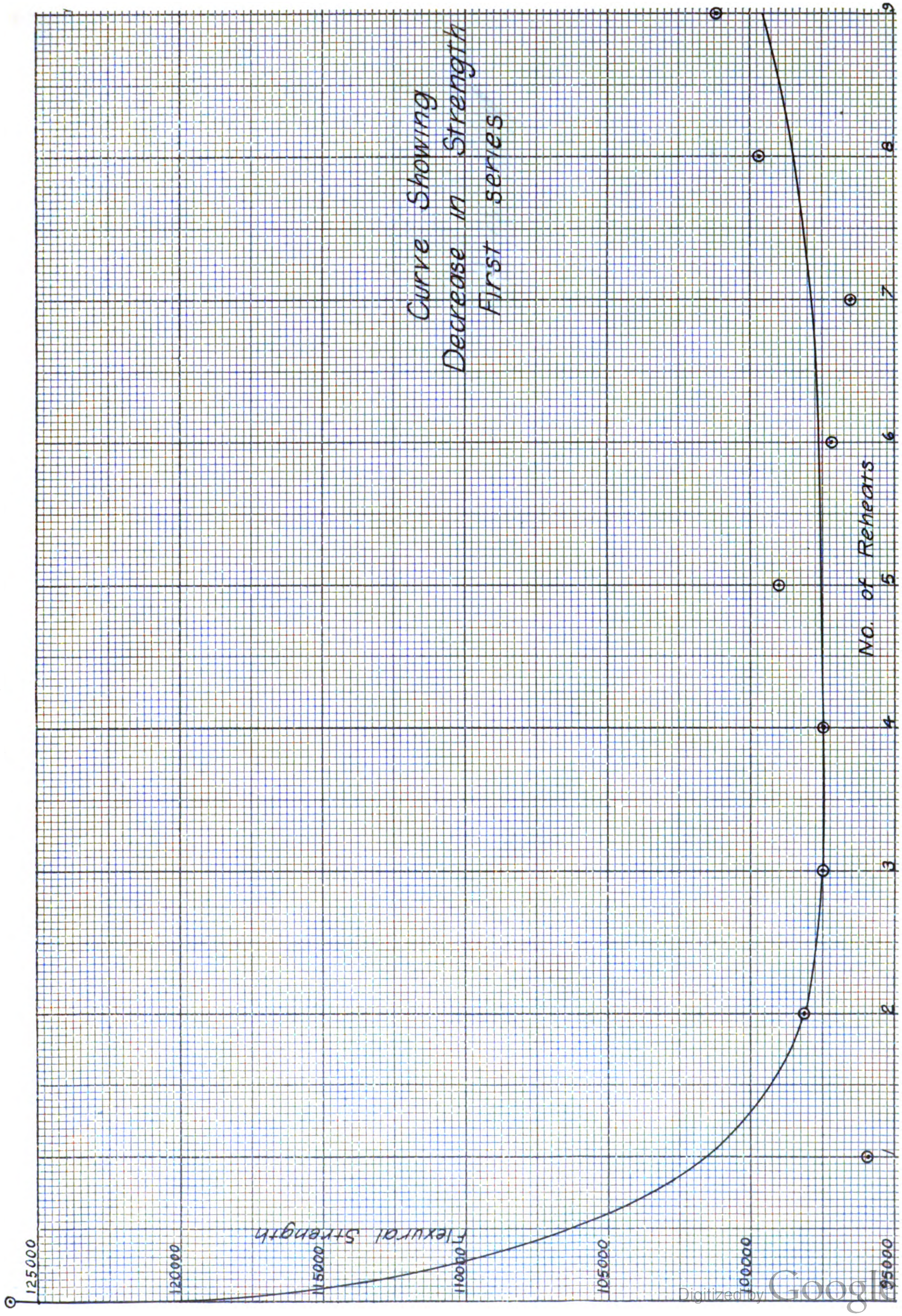
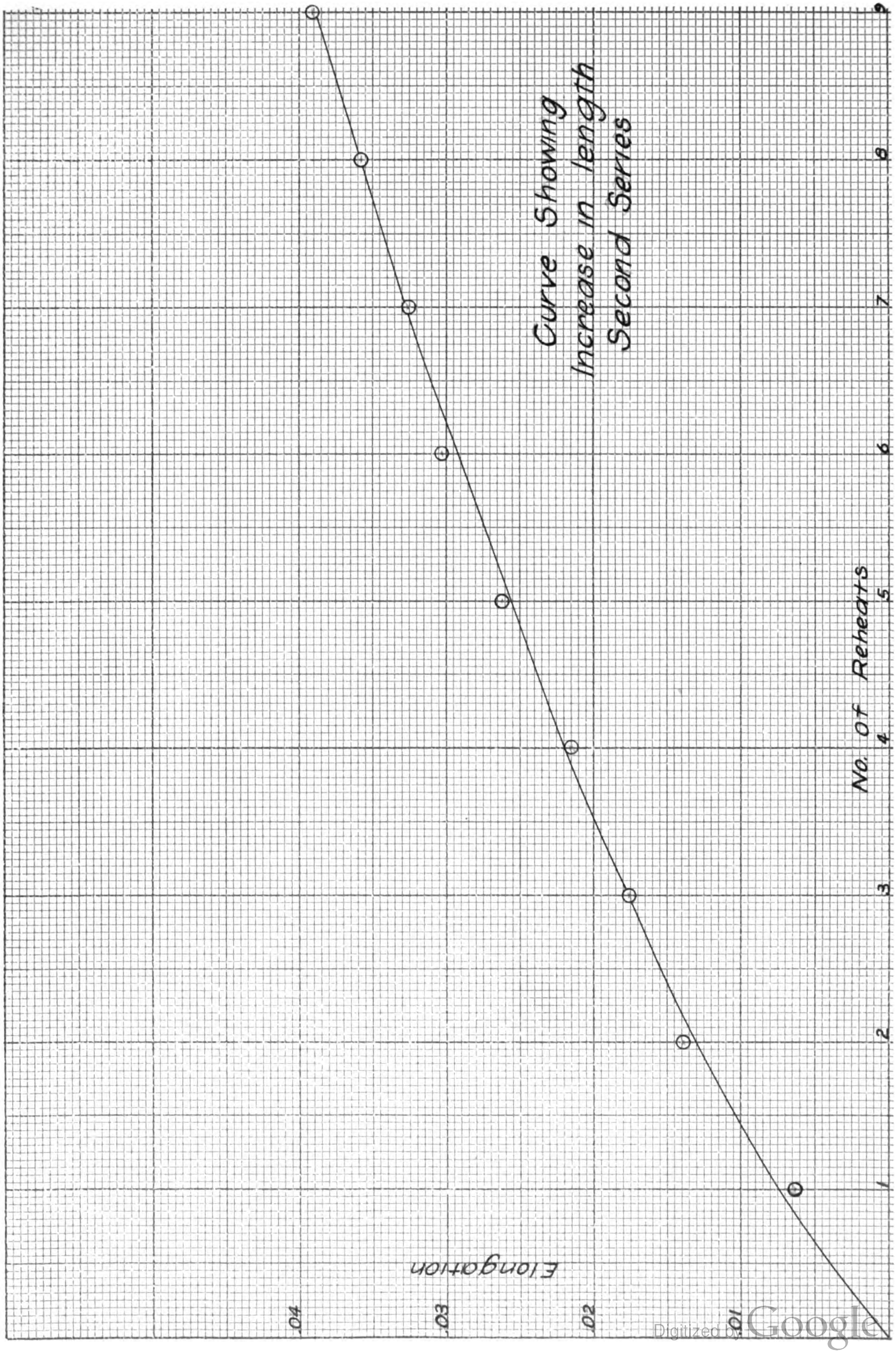
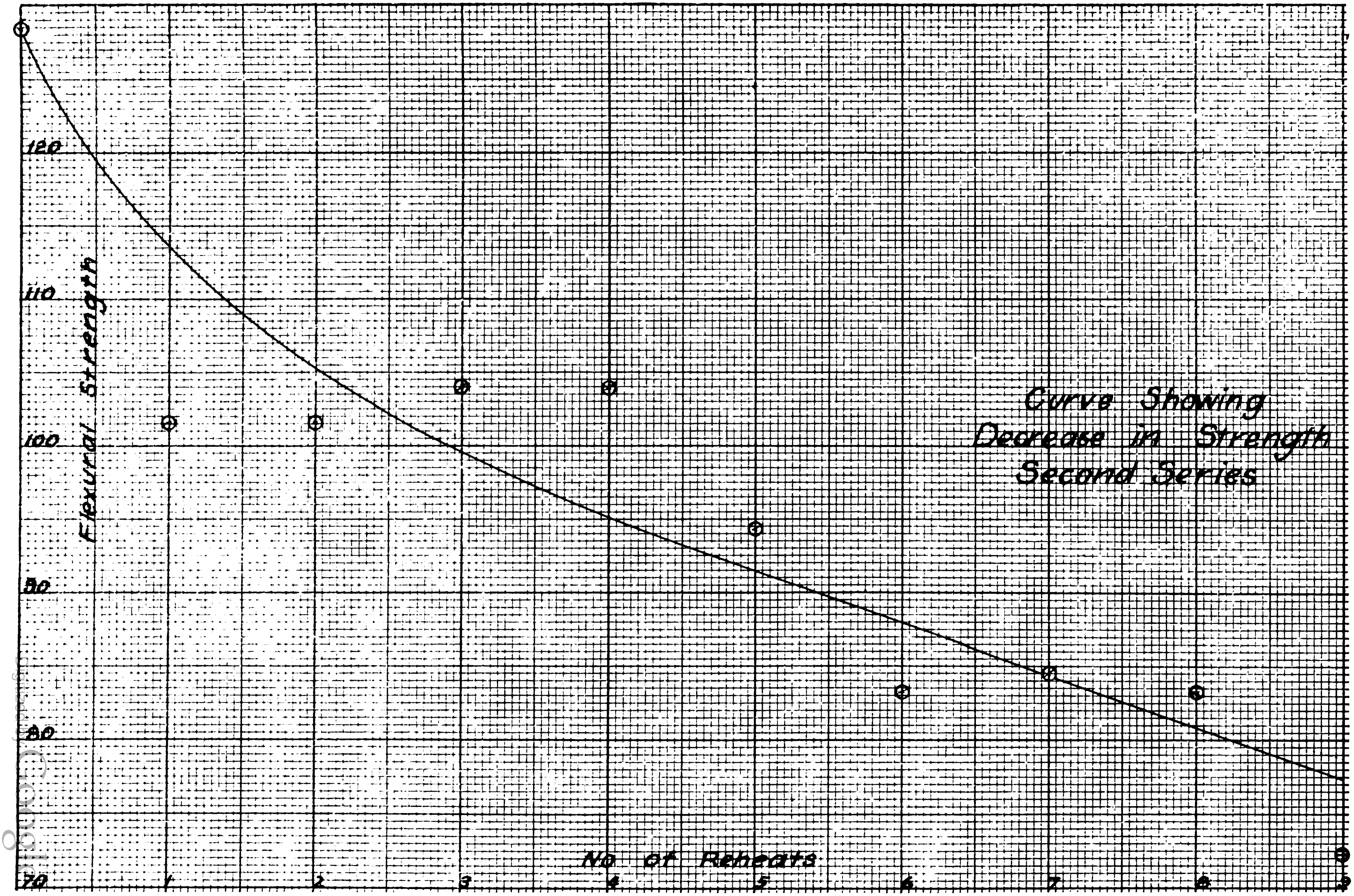

Curve Showing
Increase in Length
First Series


Curve Showing
Decrease in Strength
First series
Flexural Strength
125000
120000
115000
110000
105000
100000
95000
No. of Reheats
1
2
3
4
5
6
7
8
9


Curve Showing
Increase in length
Second Series
No. of Reheats
Elongation
.01
.02
.03
.04
1
2
3
4
5
6
7
8
9



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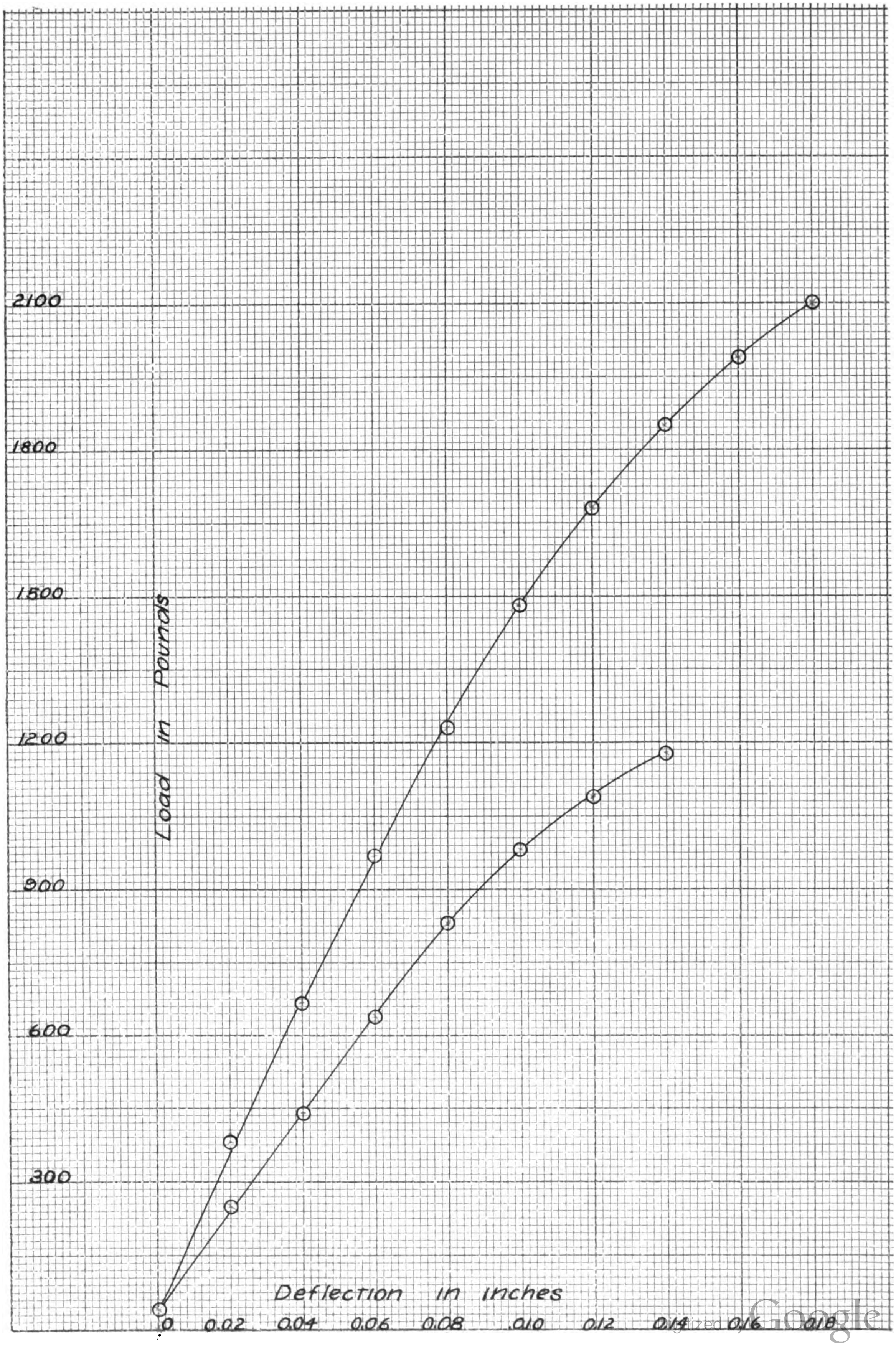
Load in Pounds
2100
1800
1500
1200
900
600
300
Deflection in inches
0
0.02
0.04
0.06
0.08
.010
0.12
0.14
0.16
0.18

APPROVED BY

Professor of Machine Design

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